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National Semiconductor

June 1999

# LM723/LM723C Voltage Regulator

## General Description

The LM723/LM723C is a voltage regulator designed primarily for series regulator applications. By itself, it will supply output currents up to 150 mA; but external transistors can be added to provide any desired load current. The circuit features extremely low standby current drain, and provision is made for either linear or foldback current limiting.

The LM723/LM723C is also useful in a wide range of other applications such as a shunt regulator, a current regulator or a temperature controller.

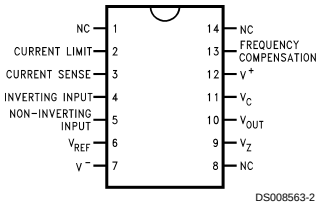
The LM723C is identical to the LM723 except that the LM723C has its performance guaranteed over a 0˚C to +70˚C temperature range, instead of −55˚C to +125˚C.

## Features

- 150 mA output current without external pass transistor
- Output currents in excess of 10A possible by adding external transistors
- Input voltage 40V max
- Output voltage adjustable from 2V to 37V
- Can be used as either a linear or a switching regulator

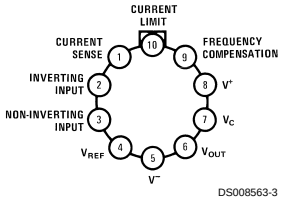
## Connection Diagrams

**Dual-In-Line Package**




**Top View**
**Order Number LM723J/883 or LM723CN**
**See NS Package J14A or N14A**

**Metal Can Package**




**Note:** Pin 5 connected to case.

**Top View**
**Order Number LM723H, LM723H/883 or LM723CH**
**See NS Package H10C**

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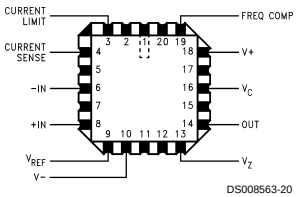
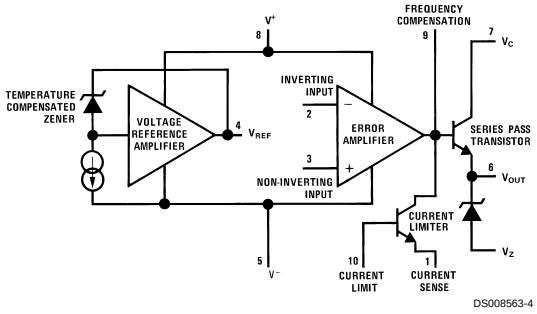
## Connection Diagrams (Continued)



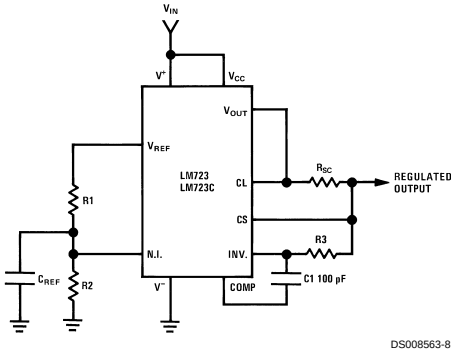

**Top View**
**Order Number LM723E/883**
**See NS Package E20A**

## Equivalent Circuit*




*Pin numbers refer to metal can package.

## Typical Application




**Note: R3** $= \frac{R1\,R2}{R1 + R2}$

for minimum temperature drift.

**Typical Performance**

| | |
|---|---|
| Regulated Output Voltage | 5V |
| Line Regulation ($\Delta V_{IN}$ = 3V) | 0.5mV |
| Load Regulation ($\Delta I_L$ = 50 mA) | 1.5mV |

**FIGURE 1. Basic Low Voltage Regulator ($V_{OUT}$ = 2 to 7 Volts)**

## Absolute Maximum Ratings (Note 1)

**If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.**

(Note 10)

| | |
|---|---|
| Pulse Voltage from $V^+$ to $V^-$ (50 ms) | 50V |
| Continuous Voltage from $V^+$ to $V^-$ | 40V |
| Input-Output Voltage Differential | 40V |
| Maximum Amplifier Input Voltage (Either Input) | 8.5V |
| Maximum Amplifier Input Voltage (Differential) | 5V |
| Current from $V_Z$ | 25 mA |
| Current from $V_{REF}$ | 15 mA |
| Internal Power Dissipation Metal Can (Note 2) | 800 mW |
| Cavity DIP (Note 2) | 900 mW |
| Molded DIP (Note 2) | 660 mW |
| Operating Temperature Range | |
| LM723 | −55˚C to +150˚C |
| LM723C | 0˚C to +70˚C |
| Storage Temperature Range | |
| Metal Can | −65˚C to +150˚C |
| Molded DIP | −55˚C to +150˚C |
| Lead Temperature (Soldering, 4 sec. max.) | |
| Hermetic Package | 300˚C |
| Plastic Package | 260˚C |
| ESD Tolerance (Human body model, 1.5 kΩ in series with 100 pF) | 1200V |

## Electrical Characteristics (Note 3) (Note 10)

| Parameter | Conditions | LM723 | | | LM723C | | | Units |
|---|---|---|---|---|---|---|---|---|
| | | Min | Typ | Max | Min | Typ | Max | |
| Line Regulation | $V_{IN}$ = 12V to $V_{IN}$ = 15V | | 0.01 | 0.1 | | 0.01 | 0.1 | % $V_{OUT}$ |
| | −55˚C ≤ $T_A$ ≤ +125˚C | | | 0.3 | | | | % $V_{OUT}$ |
| | 0˚C ≤ $T_A$ ≤ +70˚C | | | | | | 0.3 | % $V_{OUT}$ |
| | $V_{IN}$ = 12V to $V_{IN}$ = 40V | | 0.02 | 0.2 | | 0.1 | 0.5 | % $V_{OUT}$ |
| Load Regulation | $I_L$ = 1 mA to $I_L$ = 50 mA | | 0.03 | 0.15 | | 0.03 | 0.2 | % $V_{OUT}$ |
| | −55˚C ≤ $T_A$ ≤ +125˚C | | | 0.6 | | | | % $V_{OUT}$ |
| | 0˚C ≤ $T_A$ ≤ +70˚C | | | | | | 0.6 | % $V_{OUT}$ |
| Ripple Rejection | f = 50 Hz to 10 kHz, $C_{REF}$ = 0 | | 74 | | | 74 | | dB |
| | f = 50 Hz to 10 kHz, $C_{REF}$ = 5 µF | | 86 | | | 86 | | dB |
| Average Temperature Coeffic- | −55˚C ≤ $T_A$ ≤ +125˚C | | 0.002 | 0.015 | | | | %/˚C |
| ient of Output Voltage (Note 8) | 0˚C ≤ $T_A$ ≤ +70˚C | | | | | 0.003 | 0.015 | %/˚C |
| Short Circuit Current Limit | $R_{SC}$ = 10Ω, $V_{OUT}$ = 0 | | 65 | | | 65 | | mA |
| Reference Voltage | | 6.95 | 7.15 | 7.35 | 6.80 | 7.15 | 7.50 | V |
| Output Noise Voltage | BW = 100 Hz to 10 kHz, $C_{REF}$ = 0 | | 86 | | | 86 | | µVrms |
| | BW = 100 Hz to 10 kHz, $C_{REF}$ = 5 µF | | 2.5 | | | 2.5 | | µVrms |
| Long Term Stability | | | 0.05 | | | 0.05 | | %/1000 hrs |
| Standby Current Drain | $I_L$ = 0, $V_{IN}$ = 30V | | 1.7 | 3.5 | | 1.7 | 4.0 | mA |
| Input Voltage Range | | 9.5 | | 40 | 9.5 | | 40 | V |
| Output Voltage Range | | 2.0 | | 37 | 2.0 | | 37 | V |
| Input-Output Voltage Differential | | 3.0 | | 38 | 3.0 | | 38 | V |
| $\theta_{JA}$ | Molded DIP | | | | | 105 | | ˚C/W |
| $\theta_{JA}$ | Cavity DIP | | 150 | | | | | ˚C/W |
| $\theta_{JA}$ | H10C Board Mount in Still Air | | 165 | | | 165 | | ˚C/W |
| $\theta_{JA}$ | H10C Board Mount in 400 LF/Min Air Flow | | 66 | | | 66 | | ˚C/W |
| $\theta_{JC}$ | | | 22 | | | 22 | | ˚C/W |

**Note 1:** "Absolute Maximum Ratings" indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits.

**Note 2:** See derating curves for maximum power rating above 25˚C.

**Note 3:** Unless otherwise specified, $T_A$ = 25˚C, $V_{IN}$ = $V^+$ = $V_C$ = 12V, $V^-$ = 0, $V_{OUT}$ = 5V, $I_L$ = 1 mA, $R_{SC}$ = 0, $C_1$ = 100 pF, $C_{REF}$ = 0 and divider impedance as seen by error amplifier ≤ 10 kΩ connected as shown in *Figure 1.* Line and load regulation specifications are given for the condition of constant chip temperature. Temperature drifts must be taken into account separately for high dissipation conditions.

**Note 4:** $L_1$ is 40 turns of No. 20 enameled copper wire wound on Ferroxcube P36/22-3B7 pot core or equivalent with 0.009 in. air gap.

**Note 5:** Figures in parentheses may be used if R1/R2 divider is placed on opposite input of error amp.

**Note 6:** Replace R1/R2 in figures with divider shown in *Figure 13.*

**Note 7:** $V^+$ and $V_{CC}$ must be connected to a +3V or greater supply.

**Note 8:** For metal can applications where $V_Z$ is required, an external 6.2V zener diode should be connected in series with $V_{OUT}$.

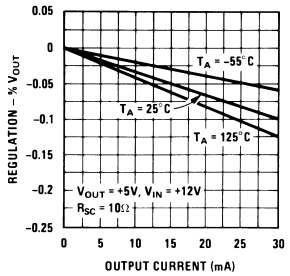
## Electrical Characteristics (Note 3) (Note 10) (Continued)

**Note 9:** Guaranteed by correlation to other tests.

**Note 10:** A military RETS specification is available on request. At the time of printing, the LM723 RETS specification complied with the Min and Max limits in this table. The LM723E, H, and J may also be procured as a Standard Military Drawing.

## Typical Performance Characteristics

**Load Regulation Characteristics with Current Limiting**

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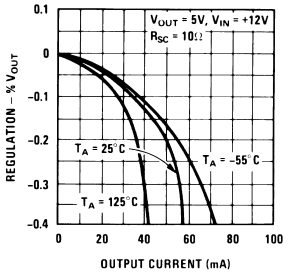
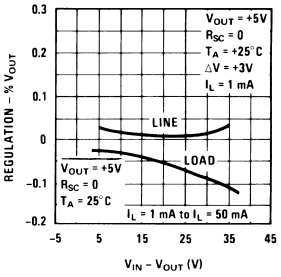
**Load Regulation Characteristics with Current Limiting**




DS008563-23

**Load & Line Regulation vs Input-Output Voltage Differential**

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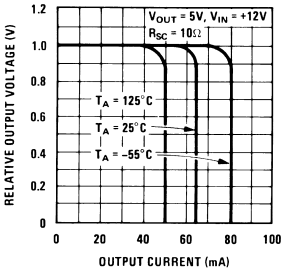
**Current Limiting Characteristics**

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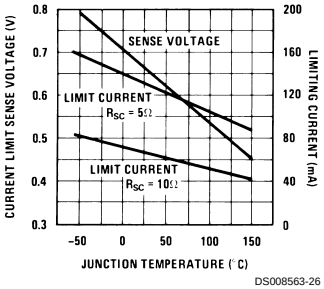
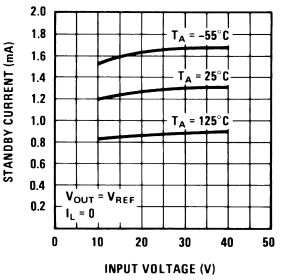
**Current Limiting Characteristics vs Junction Temperature**



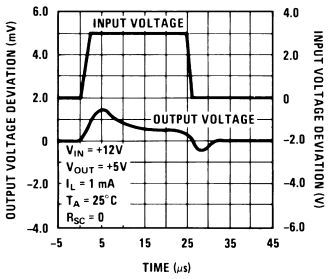

DS008563-26

**Standby Current Drain vs Input Voltage**



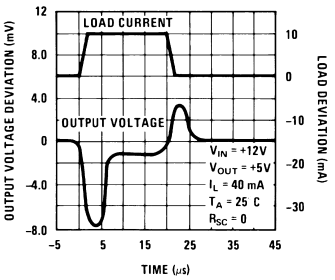

DS008563-27

**Line Transient Response**



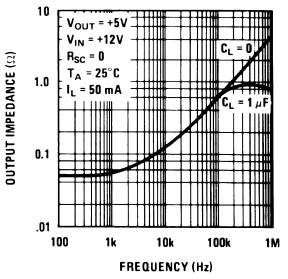

DS008563-28

**Load Transient Response**




DS008563-29

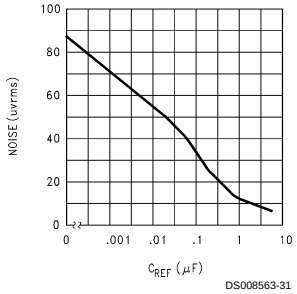
**Output Impedence vs Frequency**




DS008563-30

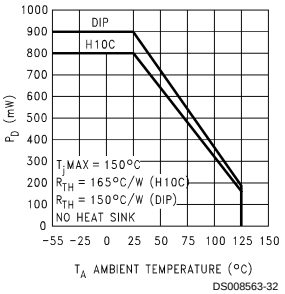
## Maximum Power Ratings

**Noise vs Filter Capacitor**
**($C_{REF}$ in Circuit of *Figure 1*)**
**(Bandwidth 100 Hz to 10 kHz)**



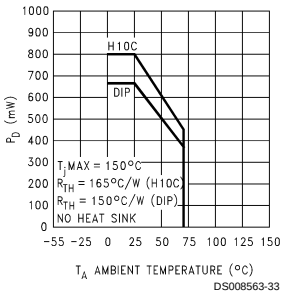
DS008563-31

**LM723**
**Power Dissipation vs**
**Ambient Temperature**



DS008563-32

**LM723C**
**Power Dissipation vs**
**Ambient Temperature**



DS008563-33

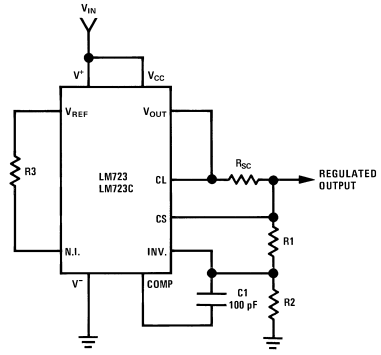
**TABLE 1. Resistor Values (kΩ) for Standard Output Voltage**

| Positive Output Voltage | Applicable Figures | Fixed Output ±5% | | Output Adjustable ±10% (Note 6) | | | Negative Output Voltage | Applicable Figures | Fixed Output ±5% | | 5% Output Adjustable ±10% | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (Note 5) | R1 | R2 | R1 | P1 | R2 | | | R1 | R2 | R1 | P1 | R2 |
| +3.0 | 1, 5, 6, 9, 12 (4) | 4.12 | 3.01 | 1.8 | 0.5 | 1.2 | +100 | 7 | 3.57 | 102 | 2.2 | 10 | 91 |
| +3.6 | 1, 5, 6, 9, 12 (4) | 3.57 | 3.65 | 1.5 | 0.5 | 1.5 | +250 | 7 | 3.57 | 255 | 2.2 | 10 | 240 |
| +5.0 | 1, 5, 6, 9, 12 (4) | 2.15 | 4.99 | 0.75 | 0.5 | 2.2 | −6 (Note 7) | 3, (10) | 3.57 | 2.43 | 1.2 | 0.5 | 0.75 |
| +6.0 | 1, 5, 6, 9, 12 (4) | 1.15 | 6.04 | 0.5 | 0.5 | 2.7 | −9 | 3, 10 | 3.48 | 5.36 | 1.2 | 0.5 | 2.0 |
| +9.0 | 2, 4, (5, 6, 9, 12) | 1.87 | 7.15 | 0.75 | 1.0 | 2.7 | −12 | 3, 10 | 3.57 | 8.45 | 1.2 | 0.5 | 3.3 |
| +12 | 2, 4, (5, 6, 9, 12) | 4.87 | 7.15 | 2.0 | 1.0 | 3.0 | −15 | 3, 10 | 3.65 | 11.5 | 1.2 | 0.5 | 4.3 |
| +15 | 2, 4, (5, 6, 9, 12) | 7.87 | 7.15 | 3.3 | 1.0 | 3.0 | −28 | 3, 10 | 3.57 | 24.3 | 1.2 | 0.5 | 10 |
| +28 | 2, 4, (5, 6, 9, 12) | 21.0 | 7.15 | 5.6 | 1.0 | 2.0 | −45 | 8 | 3.57 | 41.2 | 2.2 | 10 | 33 |
| +45 | 7 | 3.57 | 48.7 | 2.2 | 10 | 39 | −100 | 8 | 3.57 | 97.6 | 2.2 | 10 | 91 |
| +75 | 7 | 3.57 | 78.7 | 2.2 | 10 | 68 | −250 | 8 | 3.57 | 249 | 2.2 | 10 | 240 |

**TABLE 2. Formulae for Intermediate Output Voltages**

| | | |
|---|---|---|
| **Outputs from +2 to +7 volts** (*Figures 1, 4, 5, 6, 9, 12* $V_{OUT} = \left(V_{REF} \times \frac{R2}{R1 + R2}\right)$ | **Outputs from +4 to +250 volts** (*Figure 7*) $V_{OUT} = \left(\frac{V_{REF}}{2} \times \frac{R2 - R1}{R1}\right)$; R3 = R4 | **Current Limiting** $I_{LIMIT} = \frac{V_{SENSE}}{R_{SC}}$ |
| **Outputs from +7 to +37 volts** (*Figures 2, 4, 5, 6, 9, 12*) $V_{OUT} = \left(V_{REF} \times \frac{R1 + R2}{R2}\right)$ | **Outputs from −6 to −250 volts** (*Figures 3, 8, 10*) $V_{OUT} = \left(\frac{V_{REF}}{2} \times \frac{R1 + R2}{R1}\right)$; R3 = R4 | **Foldback Current Limiting** $I_{KNEE} = \left(\frac{V_{OUT}\,R3}{R_{SC}\,R4} + \frac{V_{SENSE}\,(R3 + R4)}{R_{SC}\,R4}\right)$ $I_{SHORT\ CKT} = \left(\frac{V_{SENSE}}{R_{SC}} \times \frac{R3 + R4}{R4}\right)$ |

## Typical Applications



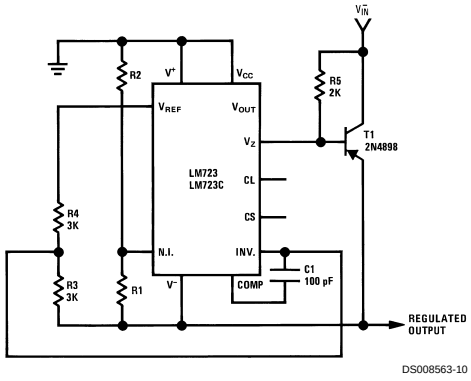

**Note:** $R3 = \frac{R1\,R2}{R1 + R2}$

for minimum temperature drift.
R3 may be eliminated for
minimum component count.

**Typical Performance**

| | |
|---|---|
| Regulated Output Voltage | 15V |
| Line Regulation ($\Delta V_{IN}$ = 3V) | 1.5 mV |
| Load Regulation ($\Delta I_L$ = 50 mA) | 4.5 mV |

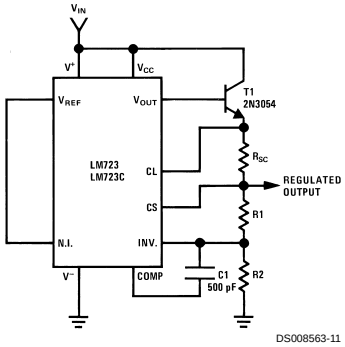
**FIGURE 2. Basic High Voltage Regulator ($V_{OUT}$ = 7 to 37 Volts)**




**Typical Performance**

| | |
|---|---|
| Regulated Output Voltage | −15V |
| Line Regulation ($\Delta V_{IN}$ = 3V) | 1 mV |
| Load Regulation ($\Delta I_L$ = 100 mA) | 2 mV |

**FIGURE 3. Negative Voltage Regulator**

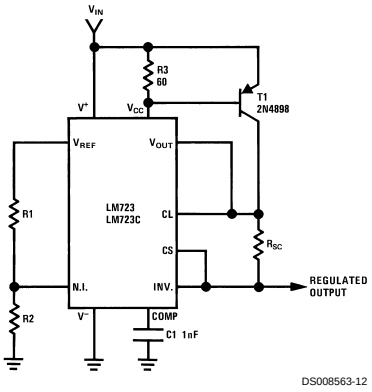



**Typical Performance**

| | |
|---|---|
| Regulated Output Voltage | +15V |
| Line Regulation ($\Delta V_{IN}$ = 3V) | 1.5 mV |
| Load Regulation ($\Delta I_L$ = 1A) | 15 mV |

**FIGURE 4. Positive Voltage Regulator (External NPN Pass Transistor)**

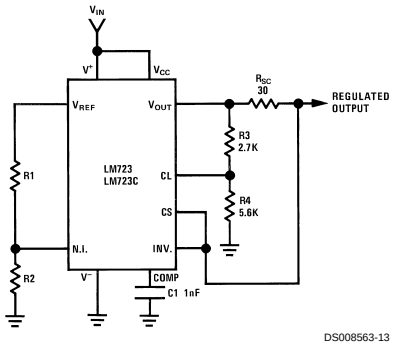
## Typical Applications (Continued)




**Typical Performance**

| | |
|---|---|
| Regulated Output Voltage | +5V |
| Line Regulation ($\Delta V_{IN}$ = 3V) | 0.5 mV |
| Load Regulation ($\Delta I_L$ = 1A) | 5 mV |

**FIGURE 5. Positive Voltage Regulator (External PNP Pass Transistor)**

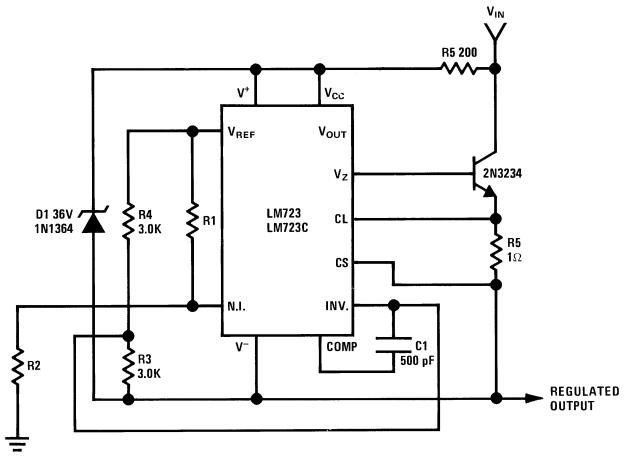



**Typical Performance**

| | |
|---|---|
| Regulated Output Voltage | +5V |
| Line Regulation ($\Delta V_{IN}$ = 3V) | 0.5 mV |
| Load Regulation ($\Delta I_L$ = 10 mA) | 1 mV |
| Short Circuit Current | 20 mA |

**FIGURE 6. Foldback Current Limiting**

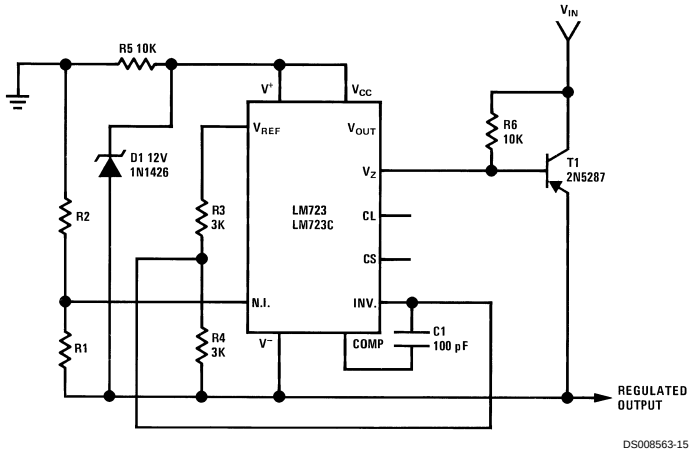
## Typical Applications (Continued)




**Typical Performance**

| | |
|---|---|
| Regulated Output Voltage | +50V |
| Line Regulation ($\Delta V_{IN}$ = 20V) | 15 mV |
| Load Regulation ($\Delta I_L$ = 50 mA) | 20 mV |

**FIGURE 7. Positive Floating Regulator**

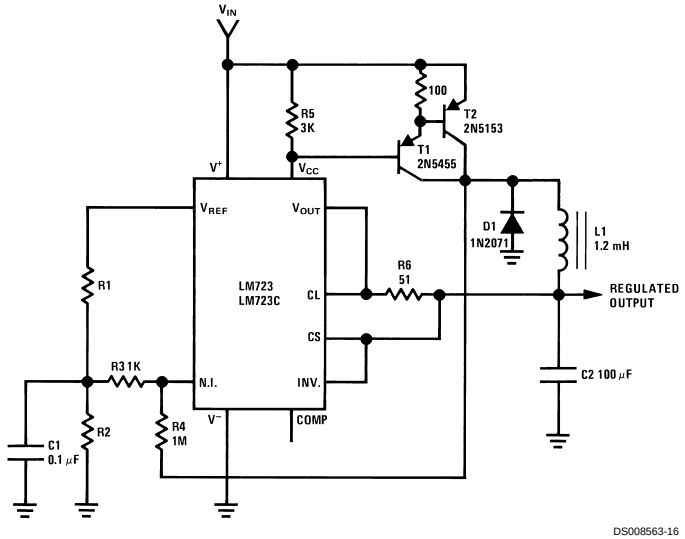



**Typical Performance**

| | |
|---|---|
| Regulated Output Voltage | −100V |
| Line Regulation ($\Delta V_{IN}$ = 20V) | 30 mV |
| Load Regulation ($\Delta I_L$ = 100 mA) | 20 mV |

**FIGURE 8. Negative Floating Regulator**

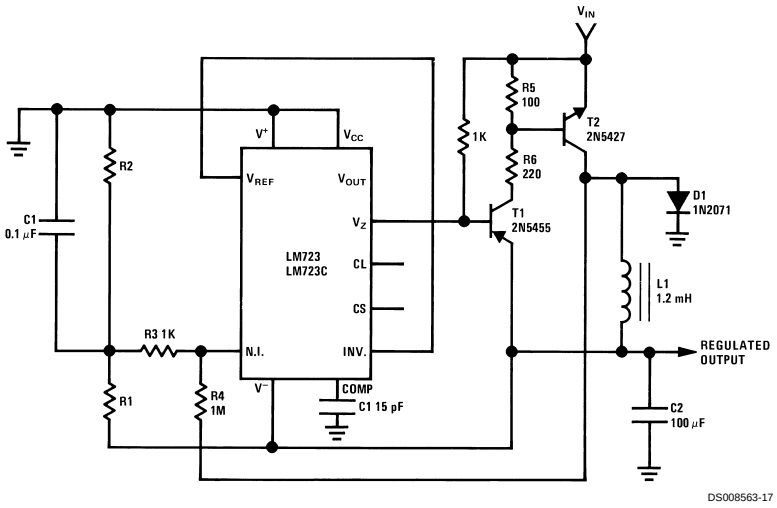
## Typical Applications (Continued)




**Typical Performance**

| | |
|---|---|
| Regulated Output Voltage | +5V |
| Line Regulation ($\Delta V_{IN}$ = 30V) | 10 mV |
| Load Regulation ($\Delta I_L$ = 2A) | 80 mV |

**FIGURE 9. Positive Switching Regulator**

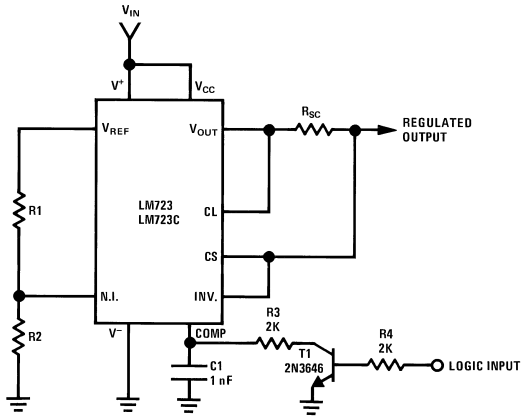



**Typical Performance**

| | |
|---|---|
| Regulated Output Voltage | −15V |
| Line Regulation ($\Delta V_{IN}$ = 20V) | 8 mV |
| Load Regulation ($\Delta I_L$ = 2A) | 6 mV |

**FIGURE 10. Negative Switching Regulator**

## Typical Applications (Continued)

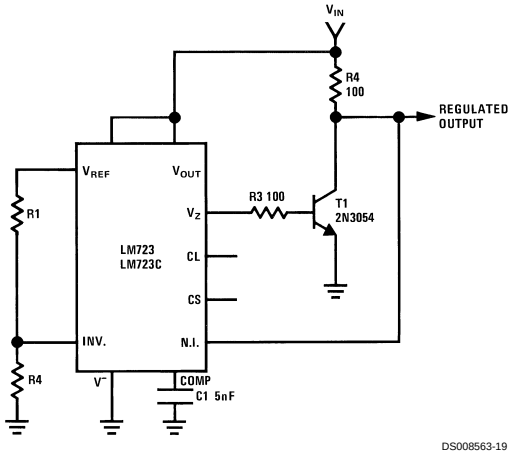



**Note:** Current limit transistor may be used for shutdown if current limiting is not required.

**Typical Performance**

| | |
|---|---|
| Regulated Output Voltage | +5V |
| Line Regulation ($\Delta V_{IN}$ = 3V) | 0.5 mV |
| Load Regulation ($\Delta I_L$ = 50 mA) | 1.5 mV |

**FIGURE 11. Remote Shutdown Regulator with Current Limiting**




| | |
|---|---|
| Regulated Output Voltage | +5V |
| Line Regulation ($\Delta V_{IN}$ = 10V) | 0.5 mV |
| Load Regulation ($\Delta I_L$ = 100 mA) | 1.5 mV |

**FIGURE 12. Shunt Regulator**

## Typical Applications (Continued)

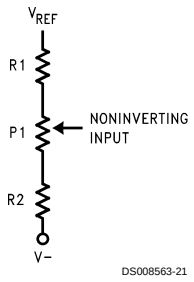
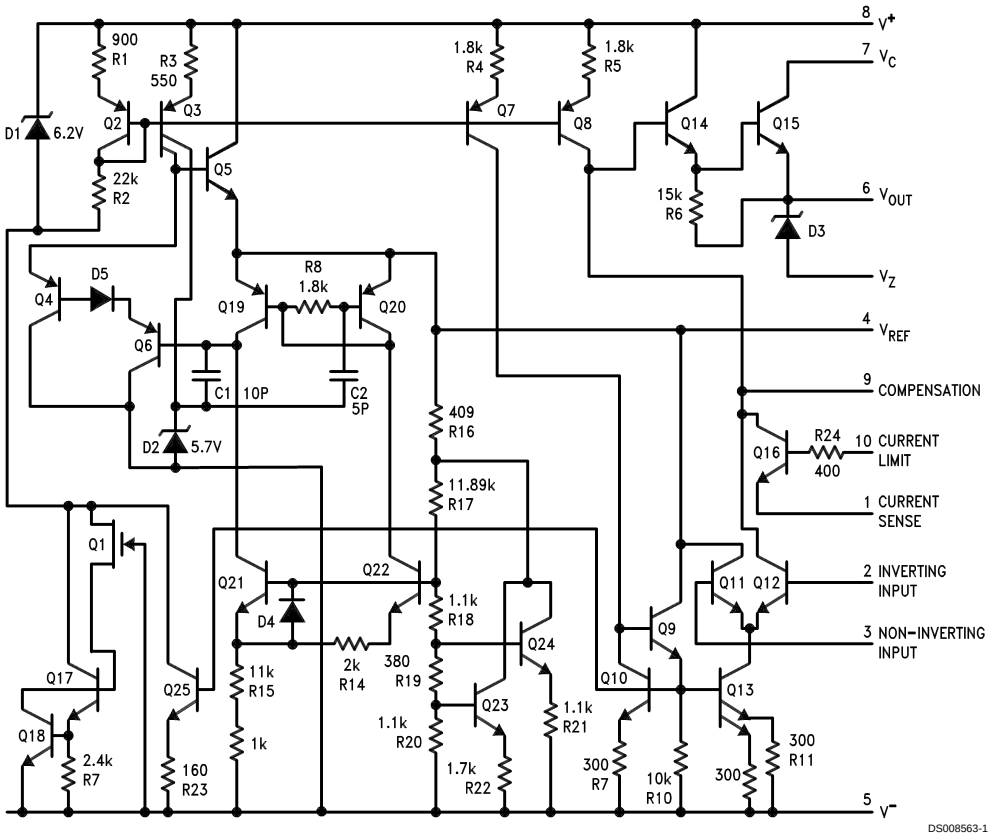
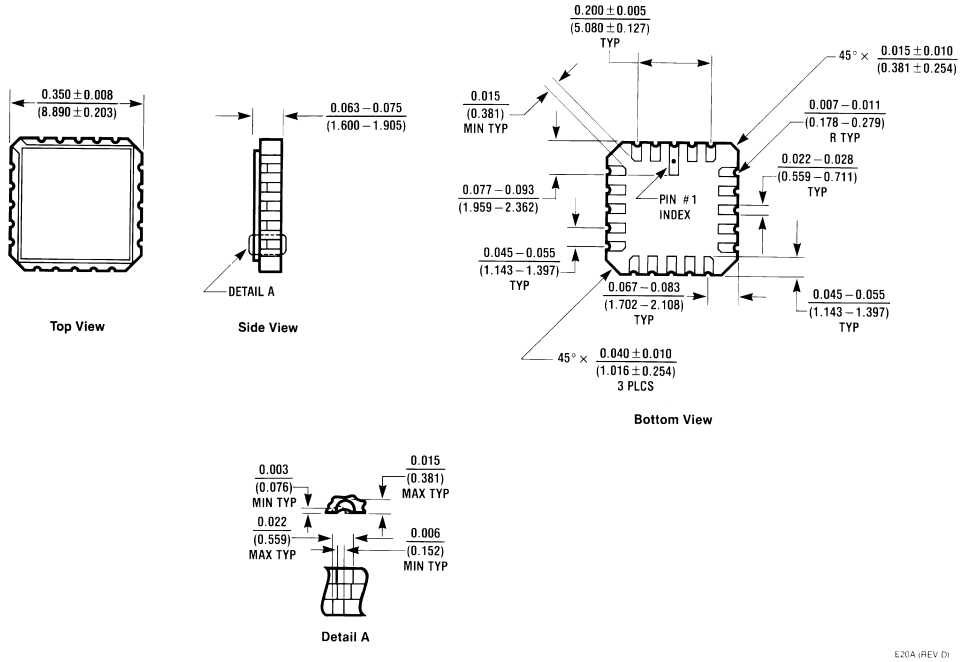



**FIGURE 13. Output Voltage Adjust**
(Note 6)

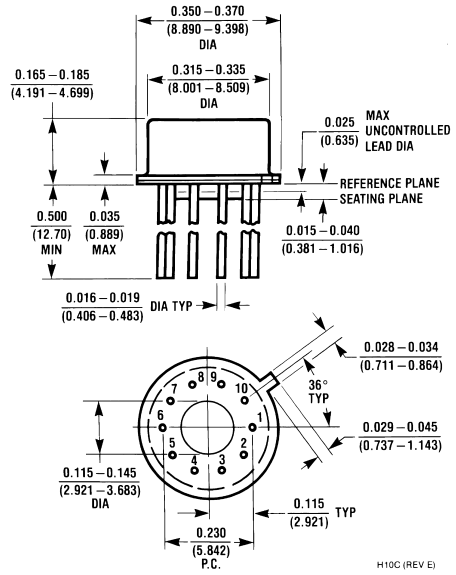
## Schematic Diagram



## Physical Dimensions inches (millimeters) unless otherwise noted

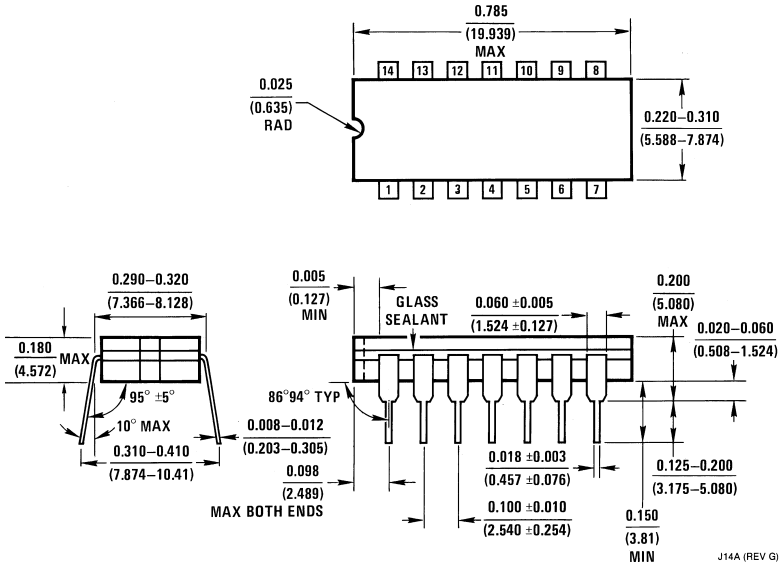



**Leadless Chip Carrier Package (E)**
**Order Number LM723E/883**
**NS Package E20A**



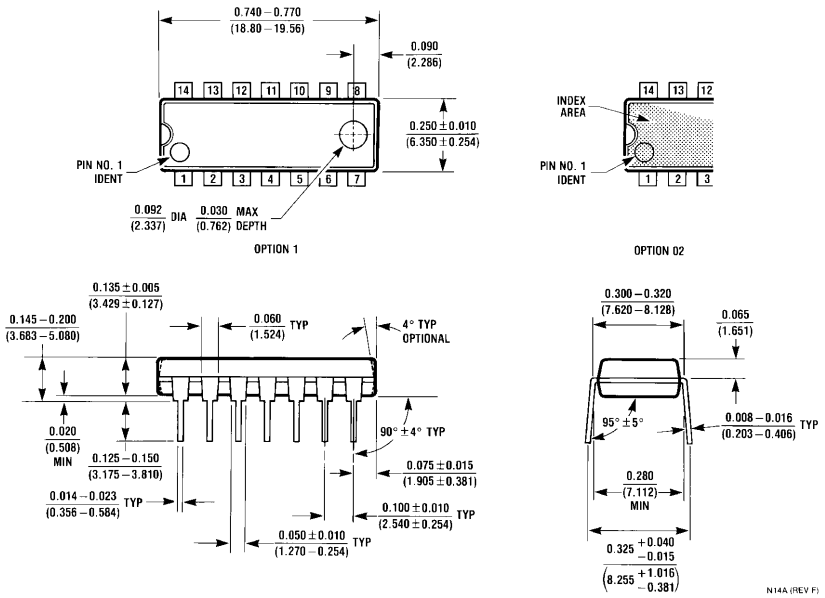

**Metal Can Package (H)**
**Order Number LM723H, LM723H/883 or LM723CH**
**NS Package H10C**

## Physical Dimensions inches (millimeters) unless otherwise noted (Continued)




**Ceramic Dual-In-Line Package (J)**
**Order Number LM723J/883**
**NS Package J14A**

## Physical Dimensions inches (millimeters) unless otherwise noted (Continued)




**Molded Dual-In-Line Package (N)**
**Order Number LM723CN**
**NS Package N14A**

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